Goliad County Aquifer Exemption : Dr. Ronald Sass Report

Adam Friedman to: Philip Dellinger 08/24/2012 04:18 PM

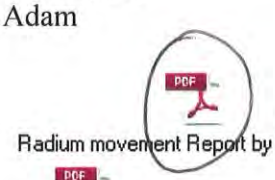
From: "Adam Friedman" <afriedman@blackburncarter.com>
To: Philip Dellinger/R6/USEPA/US@EPA

Mr. Dellinger,

Please find the attached report by Ronald L. Sass, Figures 1 – 7, and Ronald L. Sass Resume.

Please do not hesitate to contact me or Dr. Sass with any questions.

Thank you,
Adam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Movement of Radium in Groundwater from the Proposed Goliad UEC Uranium Mine Site

Ronald L. Sass
August 2012

INTRODUCTION

Radium (Ra) is an alkaline earth element, and can exist in nature only in the +2 oxidation state. In the pH range of 3 to 10, the uncomplexed ion Ra^{2+} is the dominant aqueous species for dissolved radium in natural waters. In sulfate-containing waters, precipitation and redissolution of calcium (Ca), strontium (Sr), and barium (Ba) sulfates, rather than adsorption/desorption, could control the concentrations of dissolved radium in the soil environment. Precipitation of radium is readily possible in waters where the concentrations of dissolved sulfate and carbonate are sufficiently high. This reaction, as noted by some investigators, may also be the cause for some very high adsorption values reported for radium in the literature. Very limited sorption data, especially K_d values, exist for radium on soils and sediments. The adsorption behavior of radium will be similar to that of strontium. Relative to other alkaline earth elements, radium is the most strongly sorbed by ion exchange on clay minerals. The adsorption of radium is strongly dependent on ionic strength and concentrations of other competing ions in that adsorption of radium decreases with increasing ionic strength.

Compared to most other contaminants, very limited sorption data, especially K_d values, exist for radium on soils and sediments (K_d is the ratio of the concentration of Ra in ground water to the amount of Ra that is absorbed on the aquifer material). Note that any data that indicates very high adsorption of radium on geological materials should be suspect due to the possibility that (Ba, Ra)SO_4 coprecipitation may have occurred during the measurements. Development of K_d look-up tables for radium is not possible given the minimal number of adsorption studies. However, as an alkaline earth element, the adsorption behavior of radium will be similar and somewhat greater to that of strontium for which extensive studies and data exist. Given the absence of definitive maximum and minimum K_d values for radium as a function of the key geochemical parameters, such as pH, EPA suggests that K_d values measured for radium at site-specific conditions are thus essential for site-specific contaminant transport calculations and conceptual models.

There is obviously retardation of ions such as Ra in all soils. Having noted this, about the best one can say is that Ra is least retarded by sandy soils. Clays act as ion exchangers and really retard Ra. Absorption also depends on the number of open or free exchange sites on the soil particles. They may all be already occupied or at least partly occupied by ambient ions. One can also point out that any absorbable ion distributes itself between the solid phase (aquifer material) and the solution phase (ground water). Thus, no matter how much absorption takes place, there will always be some residual Ra in the flowing ground water. How much is the question.

Also, even though the Ra is absorbed, as long as water is flowing through the aquifer, the Ra will eventually find its way back into solution and thus down dip.

Without appropriate experimental information taken from the particular hydrogeochemical site in question, no reliable estimate of the retardation of Ra from contaminated ground water can be made, even on the basis of extensive previous experience at other sites.

These introductory remarks were adapted from EPA 402-R-99-004A., "Understanding variation in partition Coefficient, K_d, values", Vol. I and EPA 402-R-04-002C, "Understanding variation in partition Coefficient, K_d, values", Vol. III.

CONTENTION

I contend that the best evidence of the groundwater-associated movement of Ra is found in the chemical analysis data from the Boundary Monitoring Wells (BMW) reported by UEC (Figure 1). All data used in the following analysis were collected and made available by UEC in its Application for Production Area Authorization dated August 27, 2008 and with related updated material.

The first non-exploratory wells to be drilled in the B-sands were the RBLB wells. These were drilled from mid May to early June in 2007 (Figure 2). The process of drilling and screening these wells has been shown to introduce oxygenated water into the B aquifer ore zone causing uranium ore to dissolve and liberating associated radium. The BMW wells were drilled and cemented during the months of February and March of 2008 (Figure 2). The first chemical analyses taken from these wells occurred on April 2, 2008 (Figure 3) or approximately 11 months later. If the liberated uranium and radium that were dissolved in the groundwater from the ore body can move between 400 and 600 feet between the time the RBLB wells were drilled and the time the first chemical analyses were taken at the BMW wells, there should be evidence of it in the analyses taken from the BMW wells. In other words the concentrations of U and Ra should be observed higher in those BMW wells located on the down gradient side of any contaminated groundwater flowing from the production area.

There is definitely a difference in the Ra concentrations found at the various BMW wells. They obviously fall into two concentration groups by 4/2/08, the date of the first chemical analysis of the BMW wells. The adjacent set of wells running counterclockwise from BMW-20 east of the production area to BMW-5 north of the production area show significantly higher radium concentrations than the remaining wells. The wells with higher Ra concentrations are shown in red (Group R) while the remaining wells are shown in blue (Group B) in the table in Figure 3 and the map in Figure 4. The first chemical tests at the BMW wells were conducted on April 2, 2008. The radium concentration measured at that time for the eight members of Group R range from 9.8 to 41.0 pCi/l of radium with an average value of 28.9 pCi/l. The radium concentration measured for the fourteen members of Group B range from 0.9 to 8.1 pCi/l of radium with an average of 2.5 PCi/l, an order of

magnitude lower than the average of Group R. The fact that the members of both groups are adjacent indicates a high degree of directionality in the presence of radium. The second chemical tests on the BMW wells were performed on July 2, 2009. The second radium analyses are very similar to those from the first analyses. By the third chemical tests on November 11, 2009 the radium concentrations of Group R were again quite similar, remaining consistent throughout this time. All eight wells had small standard deviations and there was no obvious time trend in the data. The same is true for the majority of the members of Group B. The radium concentrations all remained low except for BMW 19, which was initially higher than the others and stayed so and BMW 18, which increased from 1.8 pCi/l in the first test to 25.0 pCi/l in the third test.

Although the radium concentrations observed in test samples from both groups of BMW wells (except for BMW 18 and 19) remains relatively constant throughout the over two and one-half years between the first and the third chemical analyses, the same is not true of the uranium concentrations (Figure7, a and b). In the first analyses done in April 4, 2008, the uranium concentrations are somewhat higher in the red group than in the blue group but not very high in either. By the third analyses in November 2009, all uranium levels are less than 0.003 mg/l (Figure 3). The same relationship between Ra and U that appear in the BMW data is seen in the ore body data from the PTW and RBLB wells (Figures 5 and 6). Although, in these wells, the radium levels remain the same or increase from the initial tests to the tests in November 2009, the comparable uranium levels decrease to very small levels. The reason for this effect in the ore body is most likely due to the fact that, after the disturbance brought about by well preparation, the ore body zone returns to reducing conditions and the uranium is eventually reprecipitated as uraninite whereas the radium remains in solution, unaffected by a reducing environment. If that is also the case beyond the ore body, that would indicate that either the reduced conditions extend beyond the ore body to the areas of the BMW wells or that the groundwater movement past the BMW wells is reflective of the conditions in the ore body from which the water is flowing.

UEC claims that the local groundwater flow in the aquifer exemption area is to the east. The above argument, based solely on data obtained from UEC, supports this claim but strongly indicates that the flow moves out of the ore body in a fan shape from east to north. This would result in a groundwater flow in aquifer B that may originally move east toward the fault lines that supposedly isolate the area and then spread in directions ranging from east to north as indicated by Group R of the BMW wells. Furthermore these data are consistent with a flow rate that is greater than 400 feet per year and probably greater than 600 feet per year because they connect events at the RBLB wells to those at the Red group of BMW wells and the RBLB wells are well within the boundary of the production zone. The data also indicate that the groundwater flow is toward Fifteenmile Creek, the boundary between Goliad and De Witt Counties. This creek is roughly one mile from the mine area. Groundwater contaminants such as radium moving at a rate of 500 feet per year or more would travel from the mine area to the creek within approximately a decade.

That is unacceptable and cannot be permitted. Not only would this flow contaminate local water supplies, but also it can potentially spread beyond Goliad County and to the south.

BMW wells 18 and 19 are interesting in that they are seen to increase in radium concentration by the third chemical analysis. This analysis was conducted on November 11, 2009, almost two and one-half years after the groundwater contamination caused by the drilling of the RBLB wells. The fact that elevated radium concentrations did not appear in these two BMW wells shows that the radium arrived at these wells after being observed in Group R wells and thus was moving more slowly, perhaps by a factor of the ratio of the times between the drilling of the RBLB wells and the third tests on the BMW wells and the times between the drilling of the RBLB wells and the first tests on the BMW wells. This ratio is 21 months divided by 11 months or roughly a factor of 2. Thus the movement of radium in the direction of BMW 18 and 19 (southeast) is 200 to 300 feet per year. This movement is in the direction of two domestic wells depicted by purple dots in Figure 7. They appear to be 610 and 1535 feet from the red aquifer exemption boundary or approximately 1000 to 2000 feet from the ore body RBLB wells. This fact would predict that radium contaminated groundwater should reach the closest well in roughly three to five years and the second one in between two and three times that period.

In summary, strong empirical evidence exists in data collected by UEC showing that radium, among other hazardous materials, does migrate in the groundwater passing through the proposed uranium mine site and does so at a rate greater than 400 feet and possibly as much as 600 feet per year in a direction generally from east to north with the flow rate decreasing to about half as much tailing off to the southeast. One conclusion is that the two wells to the southeast just outside of the aquifer exemption boundary will be contaminated within a decade of drilling activity that took place in 2007. The migration route will also take the contaminants as far as Fifteenmile Creek within a decade and thus to remote areas supplied by the Creek and the waters into which it flows. It is inescapable that if a uranium mine is allowed to operate in this area, the amount of radium that the groundwater will be exposed to will be immense and so will the contamination disaster that will result both to nearby wells and to distant surface waters.

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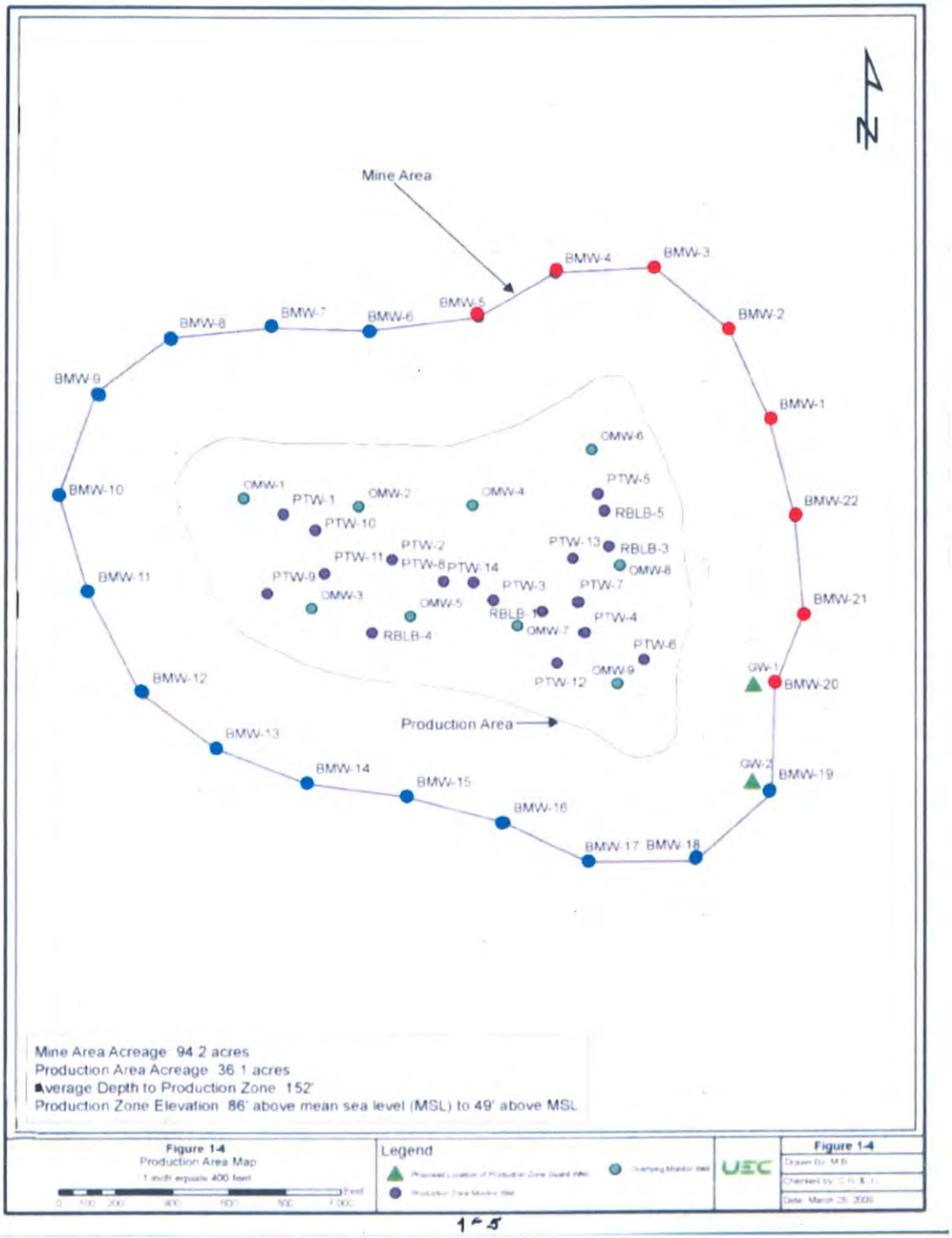
FIGURES.



1 of 5

Figure 1. Production area map showing locations of the RBLB, OMW and PTW wells within the production area and the BMW wells defining the mine area.

LeaseNum	HoleNum	DateDrilled	DateLogged	DateCemented	TD	LD
30892	RBLA-2	5/16/2007	5/16/2007	5/23/2007	140	140
30892	RBLA-3	12/8/2006	12/8/2006	12/20/2006	135	134
30892	RBLA-4	5/15/2007	5/15/2007	6/7/2007	155	155
30892	RBLA-5	5/24/2007	5/17/2007	5/25/2007	140	140
30892	RBLB-2	12/19/2006	12/13/2006	12/19/2006	110	109
30892	RBLD-1	12/18/2006	12/15/2006	12/18/2006	265	275
30892	RBLD-2	5/25/2007	5/25/2007	6/7/2007	410	410
30892	RBLD-5	12/13/2006	12/13/2006	12/13/2006	420	414
30898	RBLC-1	5/24/2007	5/16/2007	5/24/2007	290	290
30898	RBLC-7	2/1/2007	2/1/2007	2/2/2007	194	194
30898	RBLD-6	1/9/2007	1/9/2007	1/12/2007	325	326
32201	BMW-1	3/17/2008	3/17/2008	3/18/2008	205	202
32201	BMW-10	2/25/2008	2/25/2008	2/27/2008	191	190
32201	BMW-11	2/20/2008	2/20/2008	2/21/2008	183	184
32201	BMW-12	2/19/2008	2/19/2008	2/19/2008	180	180
32201	BMW-13	2/18/2008	2/18/2008	2/18/2008	185	
32201	BMW-14	2/18/2008	2/18/2008	2/20/2008	206	216
32201	BMW-15	2/14/2008	2/14/2008	2/15/2008	210	
32201	BMW-16	2/14/2008	2/14/2008	2/14/2008	195	195
32201	BMW-17	2/12/2008	2/12/2008	2/13/2008	180	
32201	BMW-18	2/11/2008	2/11/2008	2/12/2008	200	
32201	BMW-19	3/25/2008	3/25/2008	3/26/2008	199	
32201	BMW-2	3/17/2008	3/17/2008	3/18/2008	204	
32201	BMW-20	3/25/2008	3/25/2008	3/25/2008	199	200
32201	BMW-21	3/24/2008	3/24/2008	3/24/2008	200	
32201	BMW-22	3/19/2008	3/19/2008	3/19/2008	205	205
32201	BMW-3	3/13/2008	3/13/2008	3/14/2008	195	199
32201	BMW-4	3/10/2008	3/10/2008	3/13/2008	186	
32201	BMW-5	3/5/2008	3/5/2008	3/6/2008	172	
32201	BMW-6	3/4/2008	3/6/2008	3/4/2008	192	
32201	BMW-7	2/29/2008	3/3/2008	3/3/2008	190	190
32201	BMW-8	2/28/2008	2/28/2008	2/29/2008	186	183
32201	BMW-9	2/27/2008	2/27/2008	2/28/2008	190	195
32201	OMW-1	4/2/2008	4/2/2008	4/2/2008	95	96
32201	OMW-2	4/4/2008	4/4/2008	4/4/2008	110	110
32201	OMW-3	4/1/2008	4/2/2008	4/2/2008	104	
32201	OMW-4	4/3/2008	4/3/2008	4/3/2008	120	118
32201	OMW-5	4/2/2008	4/2/2008	4/2/2008	120	119
32201	OMW-6	4/3/2008	4/3/2008	4/3/2008	120	120
32201	OMW-7	4/2/2008	4/2/2008	4/2/2008	120	118
32201	OMW-8	4/3/2008	4/3/2008	4/3/2008	120	119
32201	OMW-9	4/3/2008	4/3/2008	4/3/2008	110	110
32201	PTW-1	4/1/2008	4/1/2008	4/1/2008	190	190
32201	PTW-10	8/1/2008	7/31/2008	8/1/2008	200	200
32201	PTW-11	8/4/2008	8/4/2008	8/5/2008	195	205
32201	PTW-12	8/5/2008	8/5/2008	8/6/2008	210	212

Figure 2, Drill and cementing dates and depths for various wells from the proposed Goliad UEC mining area.

32201	PTW-13			8/7/2008	216	
32201	PTW-2	4/1/2008	4/1/2008	4/1/2008	204	205
32201	PTW-3	3/31/2008	3/31/2008	3/31/2008	210	208
32201	PTW-4	3/27/2008	3/27/2008	3/28/2008	204	204
32201	PTW-5	3/31/2008	3/31/2008	3/31/2008	205	203
32201	PTW-6	3/26/2008	3/26/2008	3/27/2008	199	199
32201	PTW-7	7/30/2008		7/31/2008	201	
32201	PTW-8	8/4/2008		8/5/2008	216	
32201	PTW-9	7/29/2008	7/29/2008	7/30/2008	200	206
32201	RBLB-1	6/7/2007	5/14/2007	6/7/2007	220	218
32201	RBLB-3	5/18/2007	5/14/2007	5/18/2007	220	216
32201	RBLB-4	5/21/2007	5/15/2007	5/21/2007	220	220
32201	RBLB-5	5/14/2007	5/14/2007	5/23/2007	220	200
32201	RBLC-2	5/15/2007	5/15/2007	6/1/2007	300	295
32201	RBLC-3	6/6/2007	5/15/2007	6/6/2007	300	298
32201	RBLC-4	5/23/2007	5/14/2007	5/23/2007	280	277
32202	RBLA-1	5/21/2007	5/21/2007	5/22/2007	130	130
32202	RBLD-3	6/8/2007	5/18/2007	6/13/2007	440	440
32202	RBLD-3A	8/13/2007	8/8/2007	8/13/2007	420	420
32201	Lagarto-1				380	

Count: 66
Sum of TD: 13636 feet

Figure 2, continued

BMW 1 through 22
Wells form a closed loop of test wells, each 400 feet outside the proposed production zone
Wells fall into two catagories with members of each category adjacent to each other

Sample Date	U - 1 4/2-/08		U - 2 7/2-/09		U-3 11/11/09	Ra - 1 4/2-/08	Ra - 2 7/2-/09	Ra-3 11/11/09	U Average	Ra Average	Ra Stand. Dev.
BMW-1	0.013	<	0.003	<	0.003	28.0	39.0	33.0	0.006	33.3	5.5
2	0.017	<	0.003	<	0.003	27.0	25.0	24.0	0.008	25.3	1.5
3	0.009		0.003	<	0.003	9.8	15.0	14.0	0.005	12.9	2.8
4	0.006	<	0.003	<	0.003	29.0	29.0	26.0	0.004	28.0	1.7
5	0.015	<	0.003	<	0.003	41.0	48.0	37.0	0.007	42.0	5.6
6	0.002	<	0.003	<	0.003	2.9	9.3	4.3	0.003	5.5	3.4
7	0.004	<	0.003	<	0.003	1.8	3.9	2.7	0.003	2.8	1.1
8	0.003	<	0.003	<	0.003	1.7	4.9	0.1	0.003	2.2	2.4
9	0.188		0.003	<	0.003	1.8	2.7	3.2	0.065	2.6	0.7
10	0.001	<	0.003	<	0.003	1.5	6.4	3.4	0.002	3.8	2.5
11	0.001	<	0.003	<	0.003	1.7	1.8	2.1	0.002	1.9	0.2
12	0.008	<	0.003	<	0.003	4.9	6.2	5.7	0.005	5.6	0.7
13	0.031	<	0.003	<	0.003	2.4	2.3	5.1	0.012	3.3	1.6
14	0.001		0.003	<	0.003	1.5	1.0	1.9	0.002	1.5	0.5
15	0.001	<	0.003	<	0.003	0.9	1.3	1.5	0.002	1.2	0.3
16	0.001	<	0.003	<	0.003	1.9	2.2	2.1	0.002	2.1	0.2
17	0.002	<	0.003	<	0.003	1.5	5.1	1.7	0.003	2.8	2.0
18	0.005	<	0.030	<	0.003	1.8	4.4	25.0	0.013	10.4	12.7
19	0.008	<	0.030	<	0.003	8.1	4.3	8.5	0.014	7.0	2.3
20	0.057	<	0.003	<	0.003	40.0	42.0	40.0	0.021	40.7	1.2
21	0.029	<	0.003	<	0.003	34.0	33.0	33.0	0.012	33.3	0.6
22	0.030		0.006	<	0.003	22.0	17.0	19.0	0.013	19.3	2.5

All Uranium levels eventually revert to <0.003
All Radium values remain essentially the same over all three measurements except for BMW 18 and 19.

Figure 3. A table of uranium concentrations (mg/liter) and radium concentrations (PCi/liter) in the groundwater from samples taken from all 22 BMW wells on three occasions.

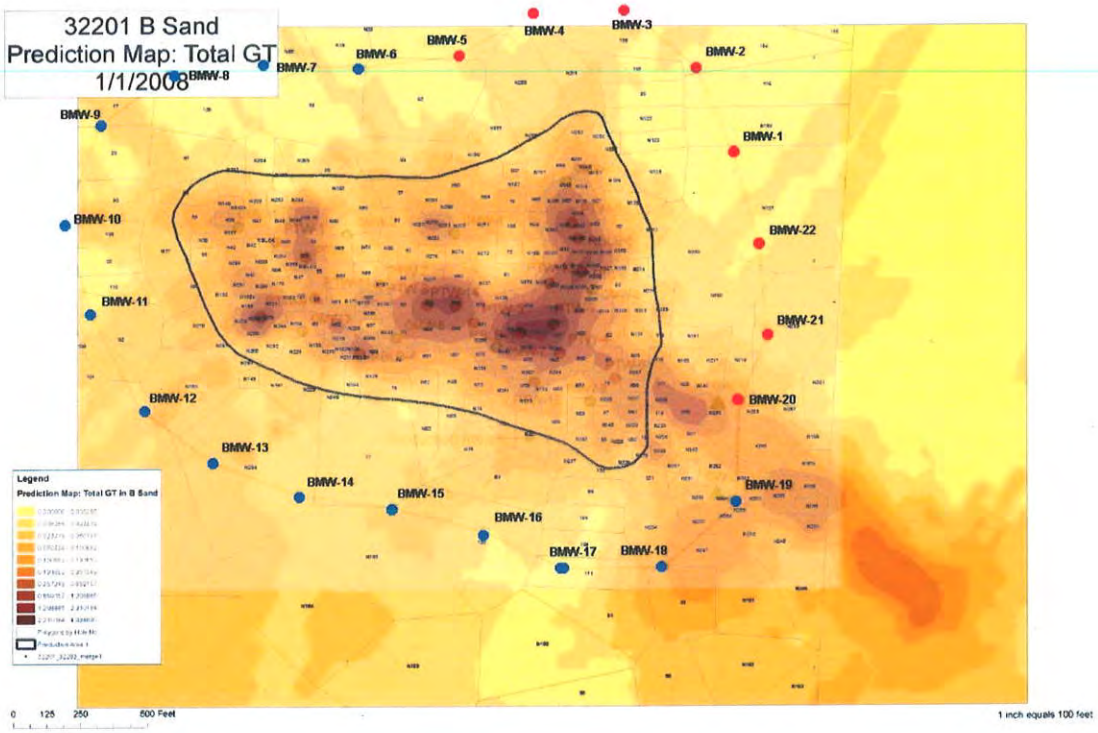


Figure 4. B sand production area showing location and concentration of uranium ore. The spatial relation of the ore bodies to the BMW wells is also shown.

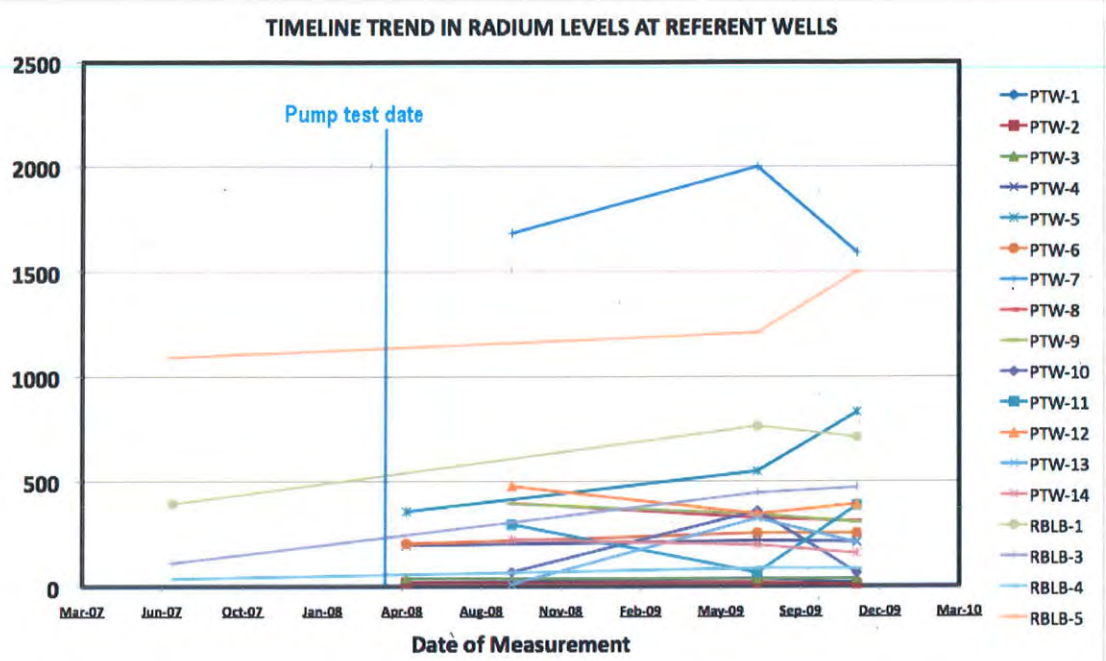


Figure 5a. Timeline trend in radium levels at reference wells.

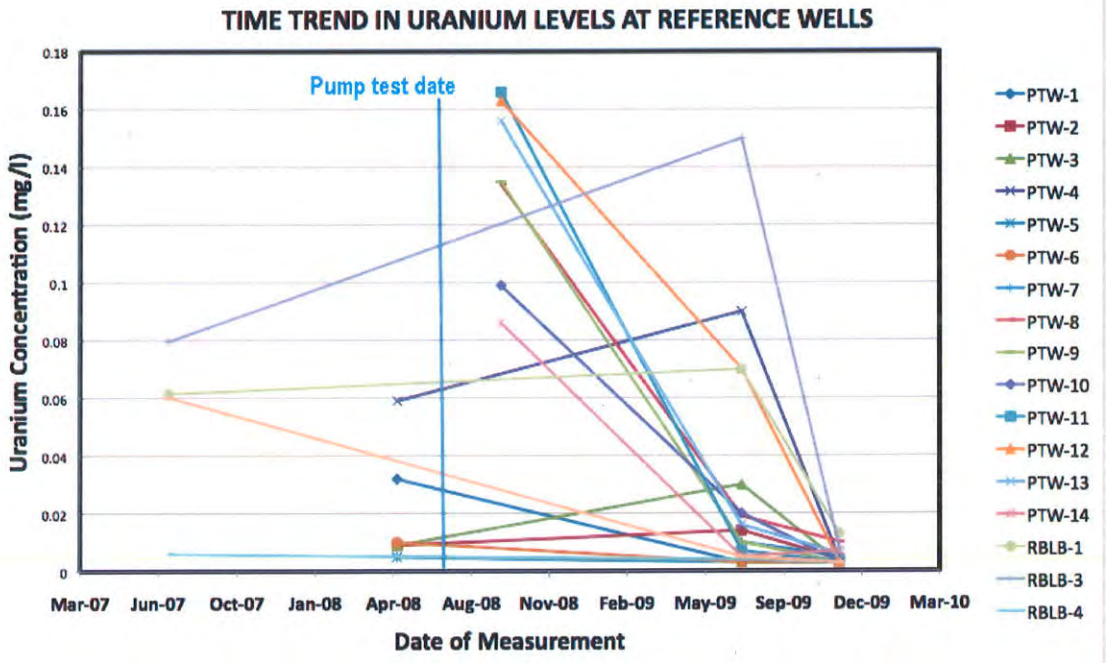


Figure 5b. Timeline trend in uranium levels at reference wells.

Test	Radium	RBLB 1,3,4,5 (PCi/l)	PTW 1-6 (PCi/l)	PTW 7-14 (PCi/l)	ALL WELLS (PCi/l)
First Test	Average	408	138	475	334
	High	1091	357	1684	1684
	Low	37	17	10	10
	Stand. Dev.	480	138	561	426
Second Test	Average	627	185	537	421
	High	1210	549	2000	2000
	Low	87	17	65	17
	Stand. Dev.	477	205	653	491
Third Test	Average	692	227	465	419
	High	1500	830	1590	1590
	Low	85	10	63	10
	Stand. Dev.	597	314	509	468

Figure 6a. Results of chemical tests for radium from RBLB and PTW wells.

Test	Uranium	RBLB 1,3,4,5 (mg/l)	PTW 1-6 (mg/l)	PTW 7-14 (mg/l)	ALL WELLS (mg/l)
First Test	Average	0.052	0.021	0.218	0.115
	High	0.080	0.059	0.804	0.804
	Low	0.006	0.009	0.099	0.006
	Stand. Dev.	0.032	0.021	0.239	0.181
Second Test	Average	0.057	0.024	0.020	0.029
	High	0.150	0.090	0.019	0.150
	Low	0.004	0.003	0.005	0.003
	Stand. Dev.	0.069	0.034	0.021	0.040
Third Test	Average	0.007	0.003	0.005	0.005
	High	0.013	0.004	0.010	0.013
	Low	0.003	0.003	0.003	0.003
	Stand. Dev.	0.004	0.003	0.003	0.003

Figure 6b. Results of chemical tests for uranium from RBLB and PTW wells.

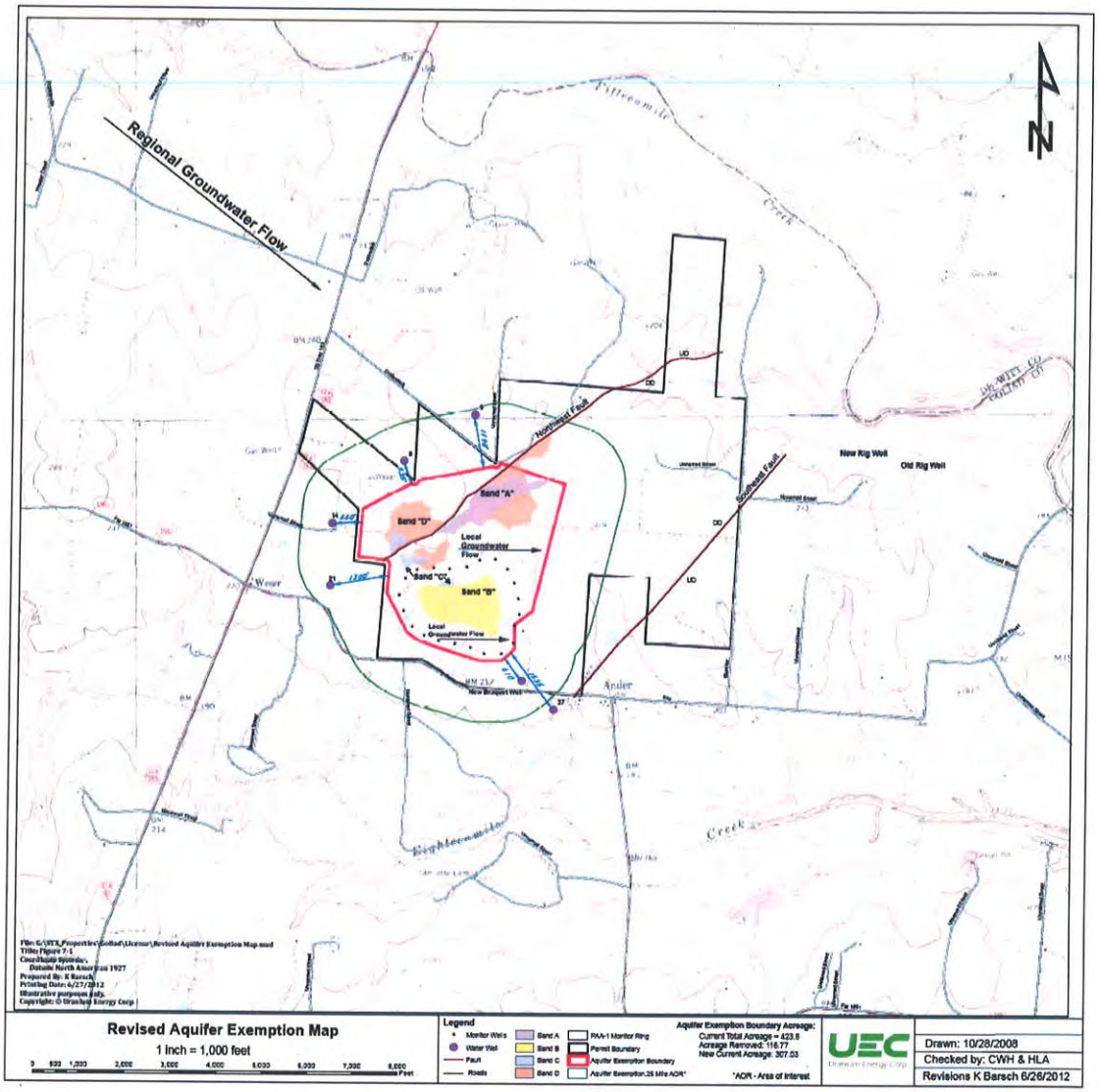


Figure 7. Revised Aquifer Exemption Map of Proposed UEC Uranium Mine Site. Note the locations of the Northwest and Southwest fault lines as well as the proposed direction of local groundwater flow.

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Sass Resume.pdf

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EDUCATION: University of Southern California, Ph.D. (Chemistry), 1957.
Augustana College, Rock Island, B.A. (Chemistry), 1954.

CURRENT POSITION Harry C and Olga K. Wiess Professor Emeritus of Natural Sciences, Rice University 2003-date
Consultant and Expert Witness on Environmental Matter, 2006-date
Fellow, James A. Baker Institute for Public Policy, 2003-present

EXPERIENCE:
Chair of Ecology and Evolutionary Biology, *Rice University* 1990-2003
Professor of Biology, Chemistry, and Education, *Rice University*, 1993-2003.
Visiting Professor, Nanjing Agricultural University, Nanjing, China, 2000.
Adjunct Professor, *University of New Hampshire*, 1999-present
Acting Chair of the Department of Education, *Rice University*, 1995-96.
Visiting Research Scientist, *NASA*, Langley, VA 1988-1989.
Chairman of Biology Department, *Rice University*, 1981-1987.
Adjunct Professor of Medicine, *Baylor College of Medicine*, 1977-present.
Professor of Biology and Chemistry, *Rice University*, 1975-1993.
Adjunct Professor of Biophysics, *Baylor College of Medicine*, 1974-1977.
Adjunct Professor of Biochemistry, *Baylor College of Medicine*, 1969-present.
Master, Hanszen College, *Rice University*, 1964 and 1966-1968.
Professor of Chemistry, *Rice University*, 1966-1975.
Visiting Professor of Theoretical Chemistry, *Cambridge University*, England, 1965.
Associate Professor of Chemistry, *Rice University*, 1962-1966.
Assistant Professor of Chemistry, *Rice University*, 1958-1962.
Research Fellow, *Atomic Energy Commission*, *Brookhaven National Laboratory*, Long Island, New York, 1957-1958.
Predoctoral Fellow, *National Science Foundation*, University of Southern California, 1954-1957.
Chemist, *United States Army, Rock Island Arsenal*, 1951-1954.

PROFESSIONAL ACTIVITIES

RESEARCH: Work is conducted in the Wetland Center for Biogeochemical Research at Rice University. Since 1988 this group has been studying the generation of biogenic atmospheric trace gases and the biological processes in waterlogged plant-soil environments leading to their formation. These gases, principally methane and nitrous oxide are important contributors to global climate change and major components of the chemical system responsible for stratospheric ozone depletion. Our work originally focused on projects sponsored by the National Aeronautics and Space Administration in

the tundra and boreal forest wetlands of Northern Canada and Alaska. Our current interests are in process studies of methane production and possible mitigation strategies for methane gas emissions from rice paddies and natural wetlands, the source of nearly half of all methane gas emitted annually to the global atmosphere.

Under the sponsorship of the US Department of Agriculture and the Ministry of Agriculture of the People's Republic of China. I traveled extensively in China to develop a cooperative effort between our laboratory and scientists in China for the study of gas emissions from Chinese and Indian rice paddies. This work began in May 1993 and has culminated in a joint research program with the National Agricultural University at Nanjing the Chinese Academy of Science Atmospheric Sciences Laboratory and the University of New Hampshire.

Most recently I have initiated a study of science policy issues related to global, regional, and local climate change. The first project is to consider various facets of the urban heat island effect in Houston, Texas. This work is sponsored jointly in the Rice University Center for the Study of the Environment and Culture and the James Baker Institute of Public Policy.

INTERNATIONAL ACTIVITIES

Convenor, *International Global Atmospheric Chemistry Program* Committee on Trace Gas Exchange in Rice Paddies (RICE). Committee members are scientific experts on atmospheric chemistry from the United States, Germany, Australia, Philippines, China, India, Thailand, and Japan. This committee is a part of the program in International Global Atmospheric Chemistry (IGAC) of the International Geosphere Biosphere Program (IGBP). The IGBP is part of the International Committee of Scientific Unions with the United States represented by the National Academy of Science. As part of this committees activities I am an editor for a book published by the Japanese National Institute of Agro-Environmental Sciences, which is the "Proceedings of CH_4 and N_2O Workshop" held in March,1992 at Tsukuba, Japan.

Member AGU Committee on Global Environmental Change. The purpose of this committee is to foster global environmental change science, to assure a home in AGU for all involved disciplines and individuales and, to provide scientific background for policy decisions. Global environmental change is meant to include large-scale chemical, biological, geological, and physical perturbations of
the Earth's atmosphere, oceans, land surfaces, and hydrologic cycle, with special attention to time scales of decades to centuries and to human-caused perturbations.

Consultant Embrapa Meio Ambiente (Embrapa Environment). Government of Brazil. Conduct workshops, train scientists, and set up experimental system to measure tracegas emissions from Brazilian irrigated rice fields.

Consultant Advisor on Graduate Programs, The Joint Graduate School of Energy and Environment King Mongkut' s University of Technology, Bangkok, Thailand

Member, Scientific Organization Committee, Workshop on GHG Emissions from Rice Fields in Asia, Chinese Academy of Science Soil Science Institute, Nanjing, China,

Consultant *Environmental Protection Agency* on Global Climate Change Issues in Agriculture. Activities I have participated in for the EPA have included workshops on various aspects of trace gas emissions, contributions to publications on atmospheric trace gases and mitigation of these gases from agricultural sources. I also serve as part of the oversight committee to monitor the EPA's program in the Philippines on the effects of increased carbon dioxide and ultraviolet radiation on agricultural crops in Asia.

Consultant *United Nations Development Program.* As a member of the External Advisory Committee to the International Rice Research Institute, I monitor the inter-regional research program on methane emission from rice fields in China, India, Indonesia, Philippines, and Thailand.

Lead Author *Organisation for Economic Co-operation and Development.* Co-authored the IPPC Guidelines on National Greenhouse Gas Inventories: Methane Emissions from Rice Cultivation (Reference Manualand Workbook). Also represented the OECD as an expert at the Twelfth Session of the IPCC in Mexico City, 1996.

Member, *National Science Teachers Association* Facilities Task Force. This committee addresses various questions of school science laboratory design and safety. It also keeps track of various regulations relating to laboratory use by students and helps teachers to be aware of them. The committee also publishes recommended designs for laboratory renovation and construction.

EDUCATIONAL ACTIVITIES

Co-director, Rice University Center for Education, 1988-date
The Center for Education at Rice University was established in 1988 as the administrative umbrella for a number of projects in school improvement in pre-kindergarten through twelfth grade.

The mission of the Center is to improve the education of children at all grade levels by identifying, fostering, and coordinating individual

projects to improve teaching and learning in pre-college environments in ways that cut across their usual isolation from each other.

Over the past several years, the Center Directors have developed several successful and ongoing programs in science, mathematics, writing, Asian and multicultural studies, early children's literacy, and in the relationships between Latino students, their families, and schools. These programs operate primarily in Houston and in some surrounding districts.

OTHER EDUCATIONAL ACTIVITIES

Minority Honors Pre-Med Academy Co-Director, 1988-1998.
College Board, Science Advisory Committee, Member 1989-1994.
Educational Testing Service, Chemistry Achievement Test Committee, 1988-1994
Academy of Science and Technology, Conroe, TX. Member Academy Advisory Council, 1988-1992.
National Center for Atmospheric Research, Education Effort Committee, 1988-date
Baylor College of Medicine, "Minority Research Apprentice Programs", Advisor, 1985-1987
Houston High School for the Health Professions, Science Curriculum Consultant, 1985-date
Fund for Improvement of Post-secondary Education, Consultant for the Life Sciences Program , 1984,1985
National Science Foundation Program to Train Master Teachers in Secondary Science Education, Mentor, 1983-1988
Conroe Texas Independent School District, Consultant, 1984-date.
Houston Mathematics and Science Improvement Consortium, Director, 1984,1985.

HONORS:

Rice University Gold Medal, 2007
Award Certificate from IPPC for the Nobel Peace Prize, 2007
The Texas Hall of Fame for Science, Mathematics and Technology, 2002
Meritorious Service Award, 2001, Association of Rice Alumni
Piper Professor for 1999, Piper Foundation, San Antonio, Texas
Citation for Excellence in Refereeing by the editors of the American Geophysical Union journals. 1998.
National Research Council Senior Research Fellow (NASA), 1988.
The Rice University Honor Certificate for Teaching, 1985.
The George R. Brown Prize for Superior Teaching, 1981.
The Rice University Student Association Mentor Recognition Award, 1976.
The Rice University Award of Highest Merit, 1972.
The George R. Brown Prize for Excellence in Teaching, 1967, 1969, 1970.
Salgo-Noren Distinguished Professor Award, 1966.
Guggenheim Foundation Fellowship (Cambridge University), 1965.
Senior Class Teaching Award, 1964.
Atomic Energy Commission Postdoctoral Fellowship, 1957-1958.
Sigma Xi, 1957.
Phi Lambda Upsilon, 1955.
National Science Foundation Predoctoral Fellowship, 1954-1957.
Phi Beta Kappa, 1954.

PROFESSIONAL SOCIETIES: *American Geophysical Union*
National Science Teachers Association

RECENT PRESENTATIONS,WORKSHOPS AND OTHER ACTIVITIES (1993-date):

"Process study of methane emission from rice paddies, " Jiangsu Academy of Agricultural Sciences, Nanjing, China, May 17, 1993

"A four year study of methane emission and production in Texas rice fields", Agro Environmental Protection Institute, Ministry of Agriculture, Tianjin, China, May 21, 1993.

Invited keynote address, International Symposium on Climate Change, Natural Disasters and Agricultural Strategies, Beijing Agricultural University, Beijing, China, May 26, 1993.

"Rice Cultivation and Trace Gas Exchange" (invited), Global Atmospheric Biospheric Chemistry: The first IGAC Scientific Conference, Eilat, Israel, April 18-22, 1993, with H. U. Neue.

"Options for Reducing Methane Emissions from Rice Cultivation" (invited), White House Conference on Global Climate Change, Washington D.C. June 10-11, 1993.

STELLA Model Demonstrations, Update (invited), Spring Meeting of the Cooperative University-Based Program in Earth System Science Education, Langley Research Center, Hampton, VA, June 22-23, 1993.

Methane Emission from Rice Paddy: IGAC Foci (keynote address), All Asian Workshop-Cum-Training Course on Methane Emission Studies, National Physical Laboratory, New Delhi, India, September 20-24, 1993.

"Methane Emission: Five Year Study at Rice University" (Invited), All Asian Workshop-Cum-Training Course on Methane Emission Studies, National Physical Laboratory, New Delhi, India, September 20-24, 1993.

IGAC Approach to Measurement Procedures (Invited), Federation of Asian Scientific Academies and Societies Seminar on Global Environment Chemistry, New Delhi, India, Sept. 27-Oct. 1, 1993.

"Tracegas Exchange with the Biosphere-I " (Invited), Federation of Asian Scientific Academies and Societies Seminar on Global Environment Chemistry, New Delhi, India, Sept. 27-Oct. 1, 1993.

"Methane Emission: Five Year Study at Rice University " (Invited), Regional Research Laboratory, Bhubaneswar, India, October 2, 1993.

"Methane Emission from Rice Fields in the United States" (Invited) International Symposium on Climate Change and Rie, International Rice Research Institute, Los Baños, Philippines, March 14-16, 1994.

Member, External Advisory Committee, United Nations Development Program, Interregional Research Program on Methane Emission from Rice Fields, Los Baños, Philippines, March 17-18, 1994.

Rice Cultivation and Trace Gas Exchange, CH_4 and N_2O Workshop, National Institute for Agro-Ecological Sciences, Tsukuba, Japan, March 23-25, 1994.

International Global Atmospheric Chemistry-Global Change & Terrestrial Ecosystems Task Team; Inaugural Meeting, Oxford UK, 8-9 December, 1994.

"A Multi-year Study of Methane Emissions from Texas Rice Fields, " Engineering Faculty, Tulane University, New Orleans, LA, March 10, 1995

"Methane Emission from Rice Paddies; A Process Study " (invited), International Symposium on Soil-Source and Sink of Greenhouse Gases, Institute of Soil Sciences (CAS), Nanjing, China, September 14-30, 1995.

Opportunities for Mitigation of CH4 Emissions from Agricultural Sources (invited IPCC Symposium), American Society of Agronomy Annual Meeting, St. Louis, MO, October 29-Nov 3, 1995.

Convenor, The NASA Workshop on Regional Assessment of Tracegas Emissions from Rice Fields of China, Rice University, November 7-9, 1995.

Member, External Advisory Committee, United Nations Development Program, Interregional Research Program on Methane Emission from Rice Fields, Bangkok, Thailand, November 19-25, 1995.

"The China Experience." Lecture Series, Rice University Homecoming December 1-3, 1995.

"Climate and Change." Rice University Summit of the Minds, February 3, 1996

"Global Change," Toward the 21st Century, Topics in Contemporary Science, Rice University, April 8, 1996.

"Who Will Feed Asia?" Rice University Alumni College, April 26-28, 1996.

Participant, IPCC/OECD Meeting of Experts on Emission Factors for Methane from Wetland Rice Cultivation, Bangkok, Thailand, April 30-May 2, 1996.

"Agricultural Practices and Other Factors Influencing Methane Emissions from Rice Fields" (Invited), IPCC/OECD Meeting of Experts on Emission Factors for Methane from Wetland Rice Cultivation, Bangkok, Thailand, April 30-May 2, 1996.

International Geosphere Biosphere Program Wetlands Workshop on Classification, University of California at Santa Barbara, May 16-20, 1996.

Convenor, The NASA Workshop on Regional Assessment of Tracegas Emissions from Rice Fields of China, Beijing, China, June 5-7, 1996.

Participant, Intergovernmental Panel on Climate Change Working Group I, Sixth Session, Mexico City , Mexico, September 10, 1996.

"Global Change: Are We Warming Up?", Rice University Families Weekend, October 4-5, 1996.

"Wetlands and Global Climate Change," Wetland Biogeopchemistry Institute, Louisiana State University, Baton Rouge, October 17, 1996.

"Mechanisms of Methane Emission from Flooded Agricultural Systems: A Modeling Study. Tulane University, New Orleans, April 4, 1997.

Rice Environmental Conference 1997, February 1, 1997 Panel Participant: The Scope of Technology in Environmental Protection

IGAC Science Advisory Council Meeting, Toronto, Ont., Canada, May 16-19, 1997.

IPCC Scientific Steering Committee, Expert Group on Methods for the Assessment of Country Greenhouse Gas Inventory Quality, National Institute of Public Health and the Environment, Bilthoven, Netherlands, November 5-7, 1997.

"Mechanisms of Methane Emission from Flooded Rice Fields: A Modelling Study. " Max-Planck-Institut für Terrestrische Mikrobiologie, Marburg, Germany, November 10, 1997

"Mechanisms of Methane Emission from Flooded Rice Fields: A Modelling Study. " UFZ-Centre for Environmental Research, Department of Soil Sciences, Bad Lauchstaedt, Germany, November 13, 1997.

TRAGNET Working Group to Synthesize Trace Gas Research in Managed and Natural Ecosystems. National Center for Ecological Analysis and Synthesis, Santa Barbara, California, December 2-6, 1997.

"A semi-empirical model of methane emission from irrigated rice fields." (Invited) Workshop of the Interregional Research Program on Methane Emission from Rice Fields in Beijing China, August 10-15, 1998 sponsored by the United Nations Development Programme Global Environmental Facility and the International Rice Research Institute.

"Exchange of methane and other trace gases from rice fields: a model system for wetland emission modeling." (Invited) The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"A semi-empirical model of methane emission from irrigated rice fields." The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"Methane emissions from rice fields: Effect of rice cultivars and plant height." The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"Global Warming and Climate Change." The Association of Rice Alumni, Alumni College, November 7, 1998. Washington, D.C.

"Agricultural Sources of Methane and Nitrous Oxide: Methane from Rice Agriculture" Invited background paper. IPCC/OECD workshop, "Good Practice in Inventory Preparation: Agricultural Sources of Methane and Nitrous Oxide." Wageningen Agricultural University (The Netherlands). February 24-26, 1999.

"Modeling Methane Emissions from Chinese Rice Paddies." Agro-Meteorological Research Center of Chinese Academy of Meteorological Sciences, Beijing, China. May 24, 1999.

"Regional and Country Level Assessment of Methane from Rice Paddies." Institute of Remote Sensing, Chinese Academy of Sciences, Beijing China, May 25, 1999.

"Factors Affecting Methane Emissions from Rice Paddies: Modeling and Remote Sensing." Institute of Natural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, China, May 26, 1999.

"A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network, Chinese Academy of Sciences, Beijing, China, May 27, 1999.

"Modeling Methane Emissions from Chinese Rice Paddies." Nanjing Agricultural University, Nanjing, China, May 31, 1999.

"A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network, Institute of Agricultural Modernization and Remote Sensing, Changsha, China, June 7, 1999.

"Modeling Methane Emissions from Chinese Rice Paddies." Guangxi Academy of Agricultural Science, Nanning, China, June 9, 1999.

"A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network Tropical Forest Station at Xi-shuang-ban-na, China, June 14, 1999.

"Monitoramento e mitigação da emissão de metano pela cultura do arroz." Invited talk to the First Brazilian Irrigated Rice Congress and the XXIII Irrigated Rice Cultivation Meeting, Pelotas, RS, Brazil, August 4, 1999.

"Modeling and Remote Sensing of Methane Emissions from Rice Paddies". Nanjing Meteorological Institute, Nanjing, China, March 25, 2000

"Global Ecosystem Dynamics", A short course, Nanjing Agricultural University, Nanjing, China, March 19-24, 2000

Session convenor: Biogeochemistry of C and N in Soils I. American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with S. Frolking

Session convenor: Biogeochemistry of C and N in Soils II Posters, American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with S. Frolking

"A Process Model of Methane Production, Oxidation and Transport in Paddy Rice Ecosystems" Invited talk, American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with Li, C. Zhang, Y. , Huang, Y., and Butterbach-Bahl, K

"Spatial Variability in Methane Emissions from Rice Fields", Department of Earth, Oceans, and Space, University of New Hampshire, August 16, 2000

"Spatial Variability in Methane Emissions from Rice Fields", Departments of Ecology & Evolutionary Biology and Earth Systems, University of California at Irvine, Nov. 3, 2000

"Seasonal and Spatial Variability of Methyl Halide Emissions from Rice Paddies near Houston, Texas" Fall Meeting of American Geophysical Union, December 15-19, 2000, San Francisco, California. With Redeker, K. , Andrews, J., Fisher F. and. Cicerone, R. J.

"Spatial and temporal variability in methane emissions from rice paddies: Implications for assessing regional methane budgets", Workshop on GHG Emissions from Rice Fields in Asia, Chinese Academy of Science Soil Science Laboratory, Nanjing, China, Feb. 26, 2001.

"Spatial Variability in Methane Emissions from Rice Fields", Nanjing Agricultural University, Nanjing, China, March 1, 2001.

"Spatial Variability in Methane Emissions from Rice Fields", Chinese Academy of Science, Atmospheric Science Laboratory, Beijing, China, March 8, 2001.

"Spatial Variability in Methane Emissions from Rice Fields", The Joint Graduate School of Energy and Environment King Mongkut' s University of Technology, Bangkok, Thailand, September 26, 2001.

"Remote Sensing of Methane Emissions from Rice Fields", The Thailand Research Fund, Program on Greenhouse Gas Emissions Assessment. Bangkok, Thailand, September 28, 2001

"Five lectures on Ecology and Global Change" Presented during an ecotourism trip on the Peruvian Amazon River. Sponsored by the Rice Alumni Association, October 20-28, 2001

"Can you see China from Texas", Rice's Best: Winners of Rice University's Teaching Awards 1999-2000, Rice School of Continuing Studies, November 19, 2001

"Global Measurement Standardization of Methane Emissions from Irrigated Rice Cultivation", Embrapa Meio Ambiente (Embrapa Environment), Jaguaruna, SP, Brazil, January 29, 2002.

"An Extensive Survey of Gaseous Emissions from Rice Paddy Agriculture", with Redeker, K R, Meinardi, S, :Blake, D, and Cicerone, R. American Geophysical Union, Spring meeting, Washington, DC., May 28-31, 2002

NACP Methane Workshop, Breakout session on process studies in atmospheric methane emissions, University of New Hampshire, September 10-12, 2002.

"Mitigation of Methane Emissions from Rice Fields", Non-CO2 Network Project on Agricultural Greenhouse Gas Mitigation, Environmental Protection Agency, Washington, DC, December 2-3, 2002.

"Human Response to the Subject of Global Warming" Conference on climate change at the Shell Center for Sustainability, Baker Institute, Houston, TX Sept. 14, 2004.

"Texas Coastal Marshes and Potential impact of Gulf of Mexico Oil Spills", U.S. Offshore Oil Exploration: Managing Risks to Move Forward, Baker Institute, Huston, TX, Feb. 11, 2011

"Gulf pf Mexico Currents and Fate of Spilled Oil", International Association of Drilling Contractors, Port of Spain, Trinidad, May 12-13, 2011

PUBLICATIONS:

Books:

CH_4 and N_2O Global Emissions and Controls from Rice Fields and Other Agricultural and Industrial Sources, NIAES Japan, 1994, Editors K. Minami, A. Mosier and R. L. Sass.

Journal Articles and Book Chapters:

1. Sass, R.L. and Donohue, J. (1957) The Unit Cell and Space Group of HCN Tetramer. **Acta Cryst.**, 10:375.

2. Sass, R.L., Vidale, R. and Donohue, J. (1957) Interatomic Distances and Thermal Anisotropy in Sodium Nitrate and Calcite. **Acta Cryst.**, 10:567-570.

3. Sass, R.L. and Donohue, J. (1958) The Crystal Structure of $S_4N_4H_4$. **Acta Cryst.**, 11:497-504.

4. Sass, R.L. (1960) A Neutron Diffraction Study on the Crystal Structure of Sulfamic Acid. **Acta Cryst.**, 13:320-324.

5. Hastings, J., Corliss, L., Elliott, N. and Sass, R.L. (1961) Magnetic Structure of Chromium Selenide. **Phy. Rev.**, 122:1402-1406.

6. Church, J.F. and Sass, R.L. (1962) A Study of the Crystal Structure of Trimethyl cis-Cyclopropane-1,2,3-tricarboxylate. **Chem. Ind**. 1574.

7. Sass, R.L. and Scheuerman, R.F. (1962) The Crystal Structure of Sodium Bicarbonate. **Acta Cryst.**, 15:77-81.

8. Strieter, F.J., Templeton, D.H., Scheuerman, R.F. and Sass, R.L. (1962) The Crystal Structure of Propionic Acid. **Acta Cryst.**, 15:1233-1239.

9. Scheuerman, R. F. and Sass, R.L. (1962) The Structure of Valeric Acid. **Acta Cryst.**, 15:1244--1247.

10. Sass, R.L. and Ratner, L. (1963) Crystal Symmetry of the Dimer of Cyclobutene-1,2-dicarboxylic Acid Dimethyl Ester. **Acta Cryst.**, 16:433.

11. Higgs, M.A. and Sass, R.L. (1963) The Crystal Structure of Acrylic Acid. **Acta Cryst.**, 16:657-661.

12. Brackett, E.B., Brackett, T.E. and Sass, R.L. (1963) The Crystal Structure of Barium Chloride, Barium Bromide and Barium Iodide. **J Phys. Chem.**, 67:2132-2135.

13. Sass, R.L., Brackett, T.E. and Brackett, E.B. (1963) The Crystal Structure of Strontium Bromide. **J. Phys. Chem.**, 67:2862-2863.

14. Sass, R.L., Brackett, E.B. and Brackett, T.E. (1963) The Crystal Structure of Lead Chloride. **J. Phys. Chem.**, 67:2863.

15. Brackett, E.B., Brackett, T.E. and Sass, R.L. (1963) The Crystal Structure of Calcium Bromide. **J. Nucl. and Inorg. Chem.**, 25:1295-1296.

16. Bugg, C.E., Lawson, J.B. and Sass, R.L. (1964) The Crystal Symmetry of Several Diazonium Salts. **Acta Cryst.**,17:767-768.

17. Dyke, M. and Sass, R.L. (1964) The Crystal Structure of Strontium Bromide Monohydrate. **J. Phys. Chem.**, 68:3259-3262.

18. Bugg, C.E., Desiderato, R. and Sass, R.L. (1964) An X-Ray Diffraction Study of Nonplanar Carbanion Structures. **J. Am Chem. Soc.**, 86:3157-3158.

19. Roth, W.R., Bang, W.B., Geobel, P., Sass, R.L., Turner, R.B. and Yu, A.P. (1964) On the Question of Homoconjugation of cis,cis,cis-1,4,7- Cyclononatriene. **J. Am. Chem. Soc.**, 86:3178-3179.

20. Desiderato, R. and Sass, R.L. (1965) The Crystal Structure of Ammionium Tricyanomethide, $NH_4C(CN)_3$. **Acta Cryst.**, 18:1-4.

21. Bugg, C.E. and Sass, R.L. (1965) The Crystal Structure of Pyridinium Dicyanomethylide, $C_8H_5N_3$. **Acta Cryst.**, 18:591-594.

22. Kilpatrick, J.E. and Sass, R.L. (1965) Structure of the X^P Matrices in the Simple Harmoniuc Oscillator Representation. **J. Chem. Phys.**, 42:2581-2586.

23. Sass, R.L. and Bugg, C.E. (1967) The Crystal Structre of Potassium p-Nitrophenyldicyanomethide. **Acta Cryst.**, 23:282-288.

24. Desiderato, R. and Sass, R.L. (1967) The Crystal Structure of cis-2- Butene Episulfone. **Acta Cryst.**, 23:430-433.

25. Dyke, M. and Sass, R.L. (1968) The Crystal Structure of Dipotassium Tetranitroethide. **J. Chem. Phys.**, 72:266-268.

26. Kronfeld, L.R. and Sass, R.L. (1968) The Crystal Structure of Dibenzothiophene Sulfone. **Acta Cryst.**, B24:981-982.

27. Herdklotz, J.K. and Sass, R.L. (1969) The Crystal Structure of 4-Methyl- thiomorpholine-1,1-dioxide. **Acta Cryst.**, B25:1614-1620.

28. Edmonds, J., Herdklotz, J.K. and Sass, R.L. (1970) The Crystal Structure of Ammonium 1,1,2,6,7,7-Hexacyanoheptatrienide. **Acta Cryst.**, B26:1355-1362.

29. Sass, R.L. and Lawson, J. (1970) The Crystal Structure of p-Sulfobenzene- diazonium Inner Salt. **Acta Cryst.**, B26:1187-1189.

30. Presley, C.T. and Sass, R.L. (1970) The Crystal Structure of 2.6-Dichloro-4- Diazo- 2,5-cyclohexadien-1-one. **Acta Cryst.**, B26:1195-1198.

31. Beall, R., Herdklotz, J. and Sass, R.L. (1970) Molecular Properties of Local Anesthetics: The Crystal Structure of Procaine Hydrochloride. **Biochem. Biophys. Res. Commun.**, 39:329-334.

32. Beall, R., Herdklotz, J. and Sass, R.L. (1970) A Refinement of the Crystal Structure of ß-Isoprene Sulfone. **Acta Cryst.**, B26:1633-1635.

33. Herdklotz, J. and Sass, R.L. (1970) The Crystal Structure of Acetylcholine Chloride: A New Confirmation for Acetylcholine. **Biochem. Biophys. Res. Commun.**, 40:583-588.

34. Sass, R.L. (1970) Molecular Properties of Local Anesthetics: The Crystal Structure of 2-Diethylaminoethyl p-Methoxybenzoate Hydrochloride. **Biochem. Biophys. Res. Commun**. 40:833-838.

35. Sass, R.L. (1970) Exploring the Nerve Cell. **The Rice Review**, Vol. 5, No. 1.pp. 16-21.

36. Sass, R.L. (1971) Profile of the Rice Experience. **The Rice Review**, Vol. 6, No.1.

37. Gansow, O.A., Beckenbaugh, W.M. and Sass, R.L. (1972) Carbon-13 Nuclear Magnetic Resonance of Pharmaceutical Agents: Benzocaine Hydrochloride Anesthetics. **Tetrahedron**, 28:2691-2696.

38. Kahler, G.A., Fisher, F.M. and Sass, R.L. (1972) The Structure of the Hinge Ligament of Spisula Solidissima. **Tex. Soc. Elect. Micro.**, 4:4-8.

39. Herdklotz, J., Werness, P. and Sass, R.L. (1973) The Crystal Structure of 2 Diethylaminoethyl p-Nitrobenzoate Hydrochloride. **J. Cryst. Mol. Struct.**, 3:271-275.

40. Billups, W. E., Chow, W. Y., Leavell, K. H., Lewis, E.S., Margrave, J. L., Sass, R. L., Shieh, J. J., Werness, P. G., Wood, J. L. (1973) Structure and Thermochemistry of Benzocyclopropenes. The Question of Bond Fixation and Strain Energy. **J. Am Chem. Soc.**, 95:7878-7880.

41. Sass, R.L. and Werness, P. G.(1973) Acetylcarnitine: on the Relationship Between Structure and Function. **Biochem. Biophys. Res. Commun.**, 55:736-742.

42. Mahajan, V. and Sass, R.L. (1974) The Crystal Structure of Acetylcholine Perchlorate. **J. Cryst. Mol. Struct.**, 4:15-21.

43. Sass, R.L. and Nichols, T.D. (1974) Crystal Structure of Tetramethylammonium 1,1,2,4,5,5-hexacyanopentadienide. **Zeit. Cristall.**, 140:1-9.

44. Goldstein, M.A., Schroeter, J.P. and Sass, R.L. (1974) Optical Diffraction Analysis of the Cardiac Z Band. **Fed. Proc.**, 33:1333.

45. Goldstein, M.A., Schroeter, J.P. and Sass, R.L. (1974) Unit Cell Z Lattice in Cardiac and Skeletal Muscle. **J. Cell Biol.**, 63:114a.

46. Goldstein, M.A., Schroeter, J.P. and Sass, R.L. (1975) Z Lattice in Mammalian Skeletal Muscle Having Different Z Band Widths at Rest Length. **J. Cell Biol.**, 67:137a.

47. Shieh, J.J. and Sass, R.L. (1975) The Molecular Structure of Palmitylcarnitine Chloride. **Biochem. Biophys. Res. Commun.**, 64:304-310.

48. Phillips, G.N., Quiocho, F. Sass, R.L., Werness, P, Emery, H. Knapp, F. and Schroepfer, G. J. Jr. (1976) Sterol Biosynthesis: Establishment of the Structure of 3-Bromobenzoylyoxy-5-Cholest-8-en-15-ol. **Bioorganic Chem.**, 5:1-9.

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